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Resources for Science Teaching & Learning for the Australian Curriculum

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PhotoMaster Format

Forces

Year 7 Physical Sciences

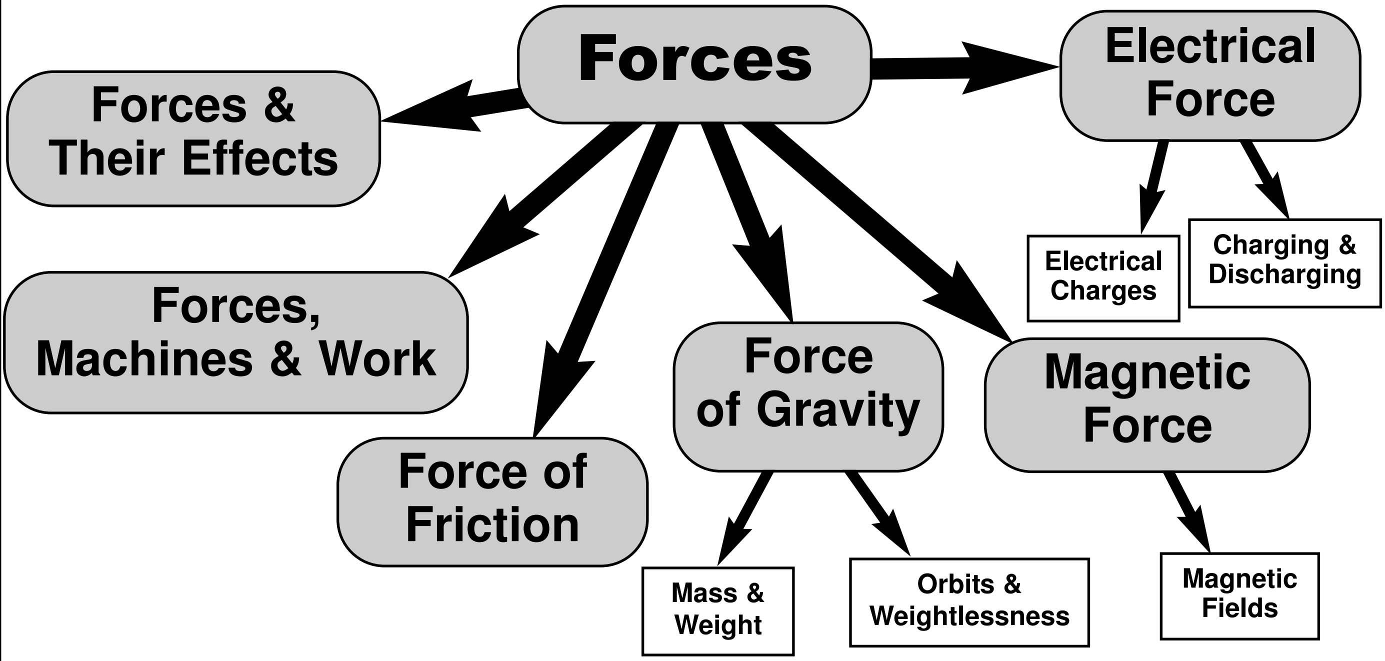
KISS topic number → Topic 06.7P ← Year level designation in Nat.Curriculum

Topic 06.7P

Science Understanding Strand
B = Biological Sciences
C = Chemical Sciences
E = Earth & Space Sciences
P = Physical Sciences

Topic Outline

This topic belongs to the branch of Science called "Physics".
Physics is the study of the physical world of forces, motion & energy.



What is this topic about?

To keep it as simple as possible, (K.I.S.S. Principle) this topic covers:

WHAT IS FORCE?
Types of Forces. How Force is Measured. Effects of Force on objects.

FORCES, MACHINES, WORK
Introduction to simple machines and the concept of "work".

THE FORCE OF FRICTION
Sometimes annoying, but vital.

THE FORCE OF GRAVITY
Mass & Weight. Orbits & being weightless.

MAGNETIC FORCE
Magnets & Magnetic Fields. Electromagnets.

ELECTRICAL FORCE
What is Electrical Charge? How things get charged up. Lightning.

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What is a FORCE?

A force is a PUSH or a PULL.

Force is what causes things to begin moving, or slow down and stop.

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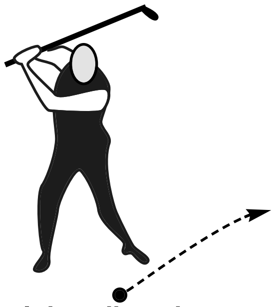
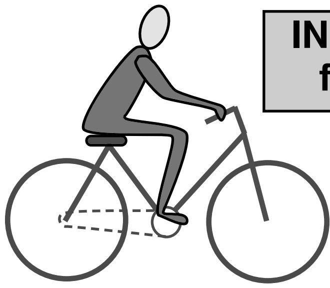
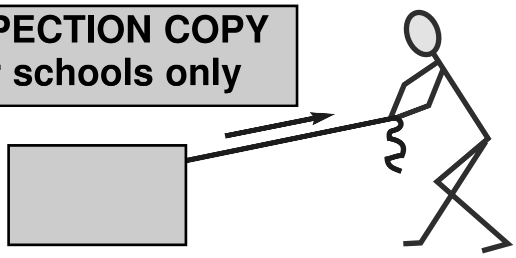


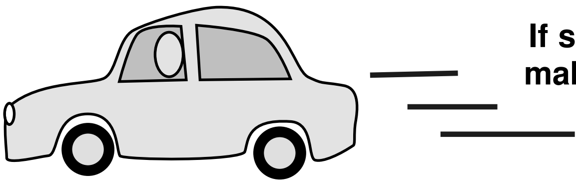
When the club strikes the ball, a force pushes to make the ball move.



Your legs push on the pedals. Wheels go around and push on the road.

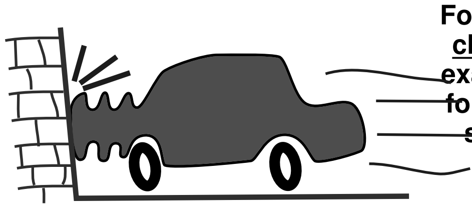


When you pull on the rope, a force is transmitted through the rope to pull on the box and drag it along.



If something is already moving, force can make it go faster, or slow down and stop.

Pressing the accelerator makes the engine supply more force to the wheels... the car goes faster.
Pressing on the brake pedal causes a force in the wheels to slow the car down.



Force can also cause a change of shape. For example, in a collision, forces can change the shape of the things involved.

Sometimes, forces can change the temperature.
In the car above, the brakes become very hot when force is used to slow the car down.

The Physics of Safety Devices

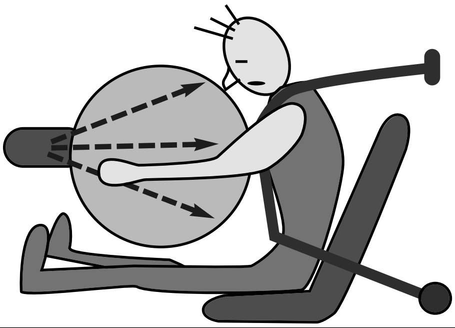
In a vehicle collision, huge forces can act on the people involved. Typically, the car comes to a sudden halt, but the driver and passengers keep moving forward, with tragic results.
People can be thrown through the windscreen, or suffer injuries by hitting the dashboard.
The driver can be impaled on the steering wheel. Rear passengers hit front passengers with lethal force.

Modern cars contain many safety devices designed to reduce injury.
The basic idea behind most of them is to reduce the forces that act on the people.
This is achieved by slowing down the sudden stop that happens. If the car and the people come to a stop over a longer time, then less force will act on them.

Safety Devices Increase the Time of the Collision. This Decreases the Forces Acting on People

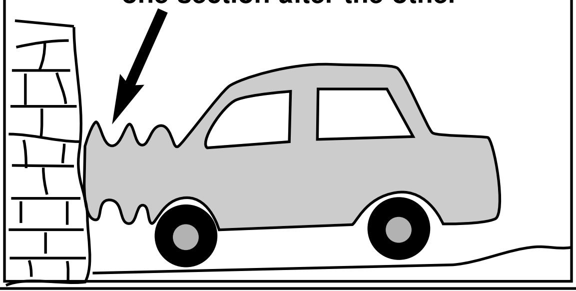
AIR BAGS

Air bags are "triggered" by a sudden jolt. A chemical explosion inflates the bag. This cushions the person (especially their head) so less force acts!



CRUMPLE ZONE in Car Body

In a collision, the car structure collapses one section after the other



The buckling of the car absorbs energy and increases the time to come to stop, so less force acts on people.

SEAT BELTS

Seat Belts restrain people, and prevent them being thrown into the dash, or through the windscreen. The belt has some "give", and stretches a bit. This increases the time involved, so less force acts!

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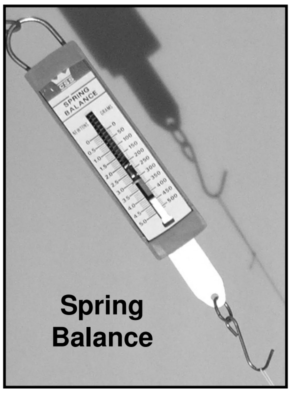
Measuring Forces

Force is measured in units called "<u>newtons</u>", abbreviated "N".

The newton unit is named after Sir Isaac Newton, an English scientist who lived about 300 years ago. He discovered many basic ideas about forces.

A simple way to measure some forces in the laboratory is to use a spring balance.



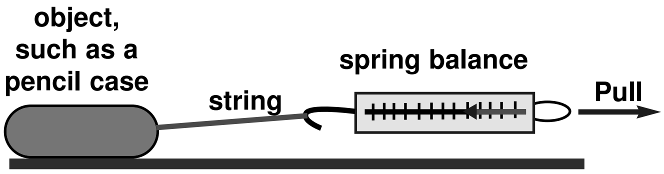
There are various models, but they all work by a spring being stretched when a force pulls on the mechanism.
(They cannot measure pushes... only pulls.)

A number scale allows you to read the size of the force in newtons.

Be aware that spring balances are NOT very <u>accurate</u> nor <u>reliable</u>.

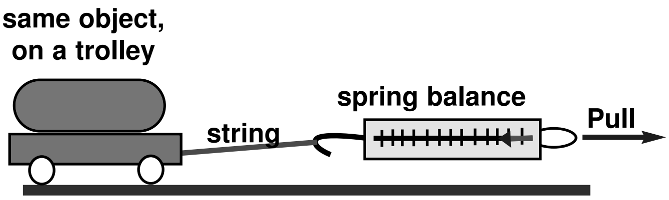
"Accurate" means that the measurement is the true and correct value.
"Reliable" means that if you repeat the same thing over and over, you always get the same answer.

To start getting an idea of how to measure forces, and some idea of how much 1N of force is, you might use a spring balance to drag various objects across the bench and measure the force required to move them.



You should read the balance scale while the object is moving along steadily.

If you measure for the same object loaded onto a laboratory trolley, you may find it requires less force to move it when on wheels.



You'll find out why, soon!

Please complete Worksheet 1

Forces Cause Movement

Here's a simple experiment you might do, or see demonstrated in class.

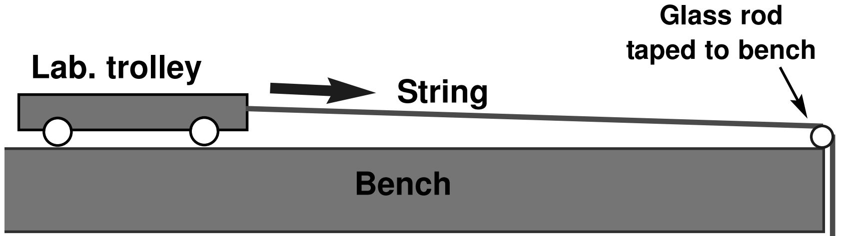
You can experiment by:

• Adding more hanging masses.
This increases the gravitational force pulling on the string.

How does this change the movement?

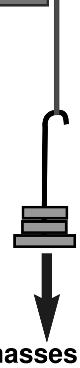
• Adding a large mass to the trolley to make it "heavier", but leave the same amount of mass hanging on the string.

How does this change the movement?



You'll find that:
• more mass on the string causes "faster" motion of the trolley.

• More mass on the trolley causes "slower" motion, for the same force pulling the string.



Slotted masses are pulled down by gravitational force

Later, you'll learn what is really meant by "mass" & "weight", and how the speed and acceleration of moving objects can be measured. For now, simply judge things "by eye".

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Putting Forces to Work

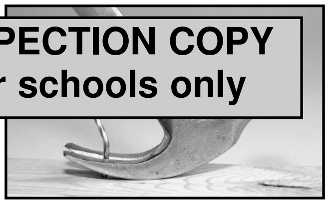
There are many situations when we need to move or lift things using force. Often it makes the task faster or easier if we use some kind of machine.

Simple Machines

A simple machine is a device which changes forces to our advantage. Simple machines include **Levers, Gears & Pulleys.**

In a later topic you will study more about simple machines. For now, we will only cover some basic ideas. An interesting activity is outlined next page.

Levers



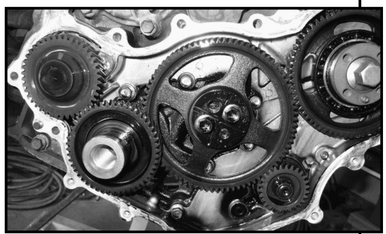
A lever is perhaps the simplest of all simple machines.

In this photo, a claw hammer is being used to pull out a bent nail. You could NOT do this easily with your fingers because the force required is too great. Using the hammer as a lever gives you a <u>force advantage</u> which easily pulls the nail.

Some simple machines make things go faster, such as a bicycle chain system.

The sprocket on the rear wheel axle is smaller then the one at the pedals. This causes the rear wheel to rotate faster than the pedals, so you gain an <u>advantage in speed</u>.

Similarly, the gear box of a car contains toothed wheels which "mesh" with each other to change the speed of rotation of the wheels compared to the engine.



In high gear, the car goes faster because it gets a <u>speed advantage</u>. In low gear, it goes slower, but can tow heavy loads or climb steep hills because the gears give a <u>force advantage</u>.

Please do the activity outlined on the next page, then come back to the section below.

Forces, Machines & Work

In everyday language, "work" means to do useful things for money.
However, in Physics "work" has a specific meaning to do with forces.

Work Done by a Force

The Physics definition of "work" is:

Work = Force x Distance

The distance involved is the distance over which the force acts. At this stage we will ignore the units of measurement. (KISS Principle)

Analysing the Pulley Results

With a knowledge of "work", now you can analyse your results of the pulley investigation (next page). Calculate as follows for each set of measurements:

a)
Work Output from the machine = Load Force X distance that load was moved

b)
Work Input into the machine = Effort Force X distance that the effort moved

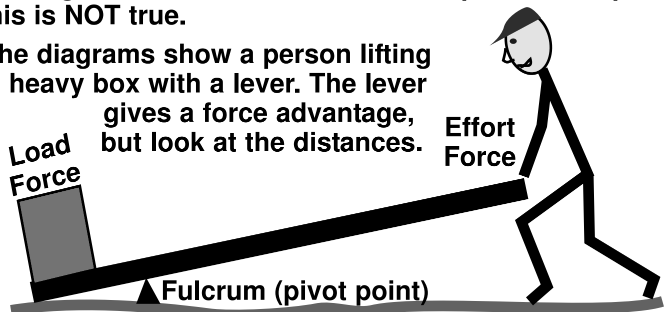
The Work Output <u>can never be greater</u> than the Work Input.

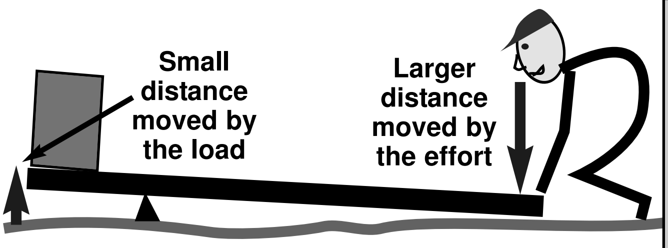
Output can be less than input, because some work gets used up with friction. In a perfect machine, output and input would be equal. However, it is a basic rule of Physics that output can NEVER be greater than input.

Work & Simple Machines

When a simple machine gives you a <u>force advantage</u>, it sounds a bit like getting something for nothing. However, in terms of Work Input and Output this is NOT true.

The diagrams show a person lifting a heavy box with a lever. The lever gives a force advantage, but look at the distances.





When you analyse the Work Input & Output you always find that you have NOT got something for nothing... the Output will always be less than the Input. There's no such thing as a free lunch!

Please complete Worksheet 2 before going on.

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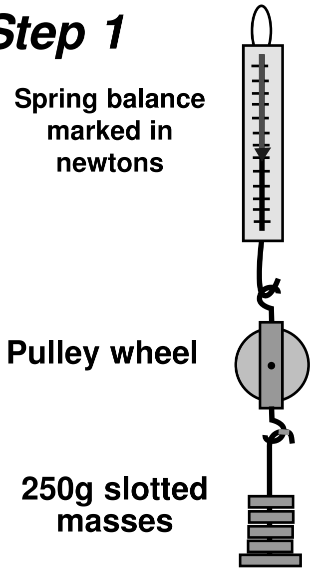
Investigating Pulley Systems

Here is an outline of a simple way to investigate the idea of the "force advantage" which some simple machines can give you.

Step 1



Weigh the combined pulley wheel and slotted masses in newtons (N).
This is the "Load" that you will lift. It will be about 3N.
This weight is the force (due to gravity) that you must overcome to lift the load.

Step 2

Set up equipment as shown, below left.

Measure the "Effort force" needed to lift the load by lifting with the spring balance.

Record all your measurements

Note: Pulleys are usually arranged so that you pull down to lift the load. We are arranging it so you lift upwards, because the spring balance will not work accurately if upside down.

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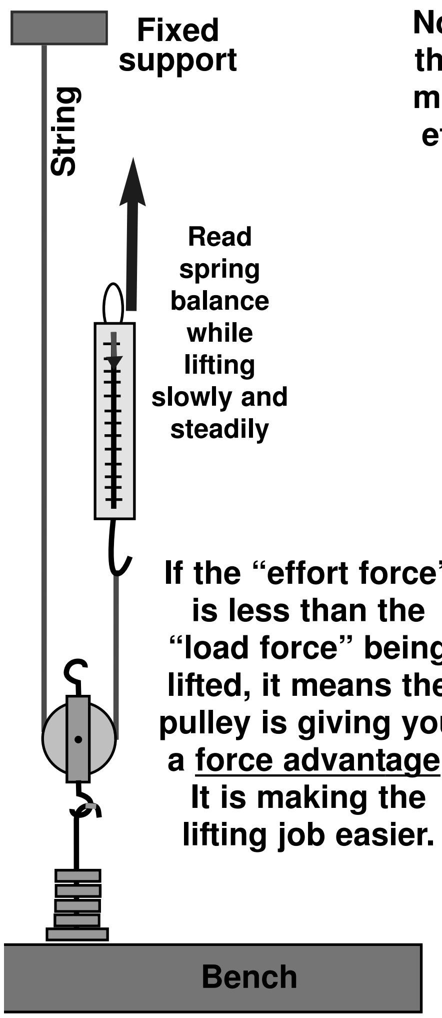
Step 2

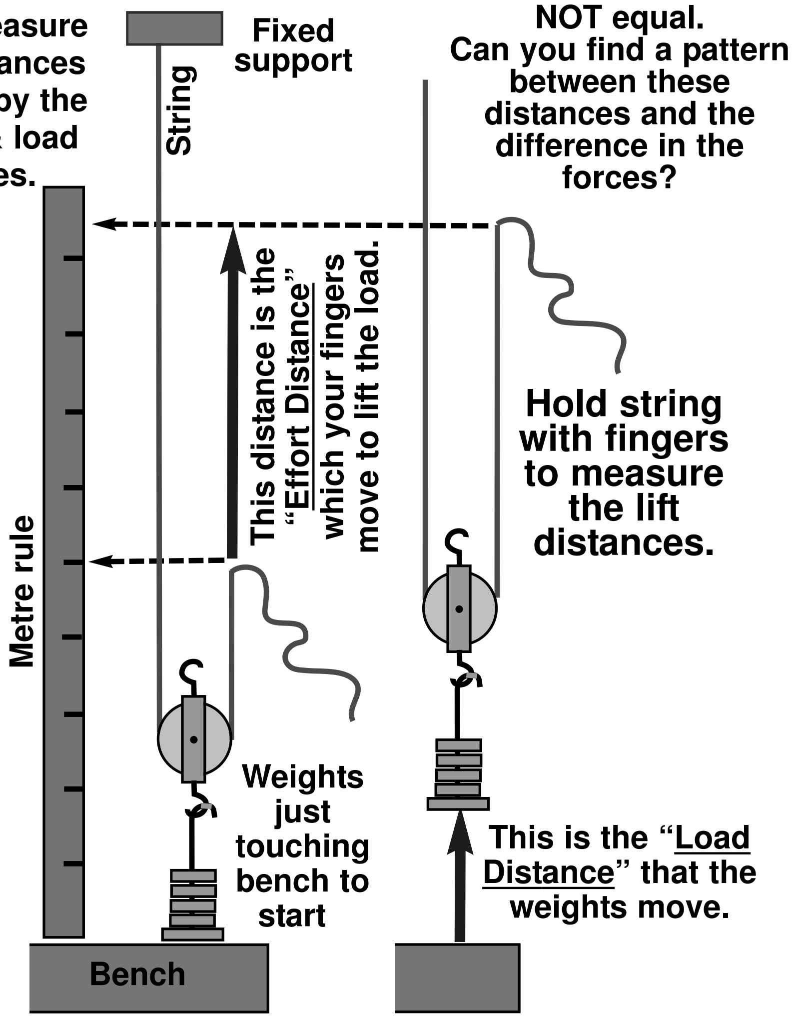


If the "effort force" is less than the "load force" being lifted, it means the pulley is giving you a force advantage. It is making the lifting job easier.

Step 3

Now measure the distances moved by the effort & load forces.

You will find that the "Effort Distance" and "Load Distance" are NOT equal.
Can you find a pattern between these distances and the difference in the forces?



You might repeat the entire experiment several times, using a different amount of "Load" each time.

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The Force of Friction

Friction is a force to know about.
Sometimes it helps us, sometimes it hinders, but it's always there.

If you roll a ball across a flat smooth surface, such as playing field, it may travel a long way, but gradually it slows down and stops.

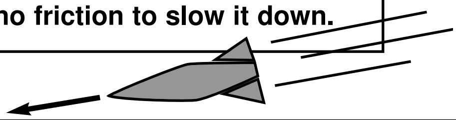
Why? It's because of "Friction".

Friction is a contact force which always pushes in the opposite direction to the way an object is moving.

If a moving object is touching anything, (the ground, the air, anything) there will be friction.

However, in outer space there is no air, so there's no friction. A moving meteor, or spaceship, will keep coasting along without slowing down.

Even with its engines turned off, the spaceship keeps flying through space. There is no friction to slow it down.

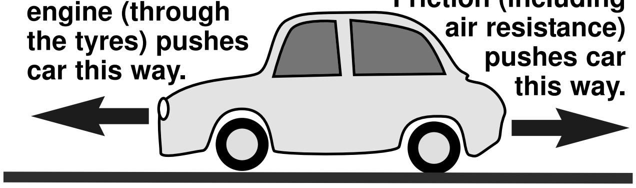


Since friction always pushes against the motion, friction always:

- slows down a moving object, and
- tries to stop any object moving any faster.

Friction is why a car's engine must keep supplying a force (through the tyres pushing on the road) just to keep going at a steady speed.

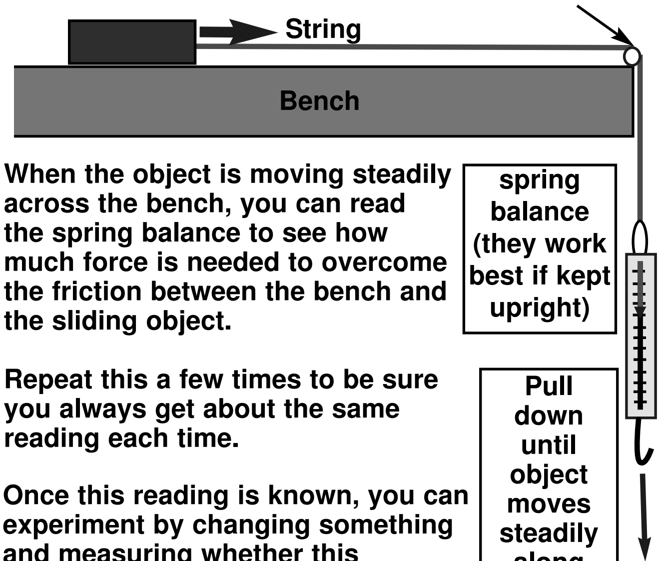
If the engine force (pushing the car forward) is the same strength as friction (pushing backwards) then the forces "balance out" and the car travels at a constant speed.



To go faster, the driver must increase the engine thrust force so it is bigger than the friction force. To stop, the driver increases the friction force by pressing the brakes, and also lets the engine force die down to nothing.

What Affects Friction?

Sometimes there's a lot of friction, sometimes not so much. What factors control this? Perhaps you can investigate this idea by doing some experiments as suggested below.



When the object is moving steadily across the bench, you can read the spring balance to see how much force is needed to overcome the friction between the bench and the sliding object.

Repeat this a few times to be sure you always get about the same reading each time.

Once this reading is known, you can experiment by changing something and measuring whether this increases, or decreases it.

The higher the reading on the spring balance, the more friction.

Some Factors to Change

1. Force Between the Object and the Bench

Try pressing gently downward on the object while it is being dragged across the bench.

You could also place an extra weight on top of it. This makes it heavier, so it presses harder on the bench.

How does this change the friction?

2. The Surfaces in Contact

Place a smooth, flat sheet of glass between object and bench. Try a sheet of metal. What about a sheet of sandpaper?

What if you wet the bench with water?

What about a sheet of glass with oil or grease on it?

You should be able to relate your results to events such as what happens to cars on wet, or greasy, roads.

Examples Involving Friction

(or lack of friction!)

Accelerating, Stopping or Turning a Corner

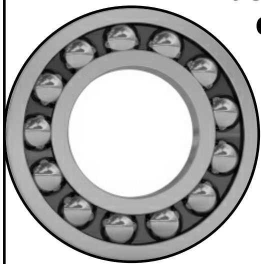
If it wasn't for friction no vehicle could ever get moving, and if it did, it could never turn a corner or stop again. Friction between the tyres and the road gives the "grip" which allows the tyres to push against the road. Without that grip it would be impossible to:

- get a stationary vehicle moving, or
- turn a corner, or
- slow down and stop.

Think about what happens when roads are wet or icy. Cars skid sideways, or can't stop and have "rear-end" collisions. Wet or icy conditions reduce friction and make driving much more hazardous.

These "fat" racing tyres cause more friction, so they have more grip.

Wheels and Wheel Bearings



It's good to have friction "grip" between tyres and road, but while you're cruising along it's better to have no friction to slow you down. The rolling action of a wheel has much less friction than dragging a wheel-less vehicle over the ground.

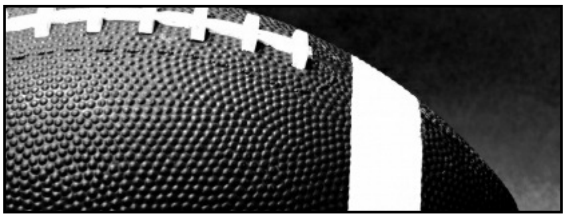
A "bearing" is a low-friction device which joins a wheel to its axle. This rotates freely and keeps friction to a minimum, especially if it is well lubricated with grease or oil.

Dimples on a Footy Ball

Traditionally, the ball for Rugby, or League or Aussie Rules was made from leather. When wet, these could be slippery and cause a lot of mistakes in the game.

Modern balls are often made of a plastic with small dimples all over.

This increases the friction between ball and hand or boot so there are less handling errors, even in wet weather.



Velcro

Perhaps the ultimate in friction! It's just 2 different pads of nylon material, but once they are pressed together, friction holds them so that they keep your sneakers on, or your pants up.

Notice that it's easy to pull them apart by lifting one side up from the other.

However, it is very difficult to pull them apart sideways.

Please complete Worksheet 3 before going on.

Cold Hands? Friction Can Help

On a cold day people rub their hands together to warm them up.
Remember that forces can change the movement of an object, or its shape, or even its temperature. Friction forces often result in an increase in temperature. Rubbing your hands together creates friction, which raises temperature, so your hands get warmer.

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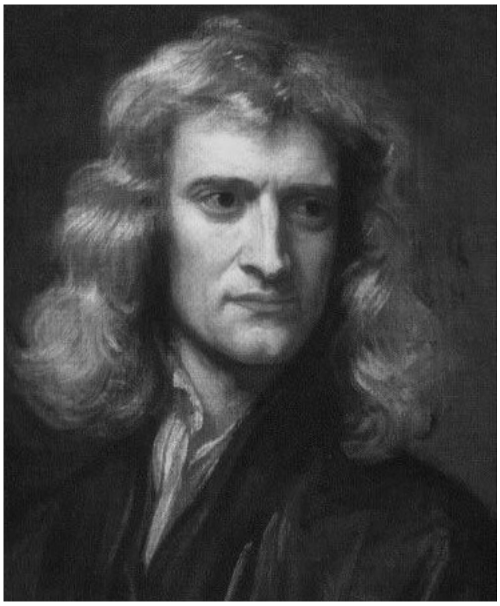
A Little History

Until about 300 years ago, the concept of "force" had not been thought of in a scientific way. It seemed "natural" that an apple from a tree would fall down. People thought that down-on-the-ground was the "natural place" for all things. Things fell down because they were trying to get to their "natural place".



Similarly, it was considered "natural" for a moving object to slow down and stop. No reason for this... it was just "natural".

These ideas were overturned by Sir Isaac Newton (1642-1727). He figured out that all these things were due to forces. A moving object will keep moving unless a force acts on it.

In everyday situations, things slow down and stop because friction force stops them. Apples fall down because of gravitational force.

You will learn more about these things, and Sir Isaac Newton, in future studies.

Contact Forces and Field Forces

All the forces described so far are "Contact Forces" because they act only if the force is in contact with something.

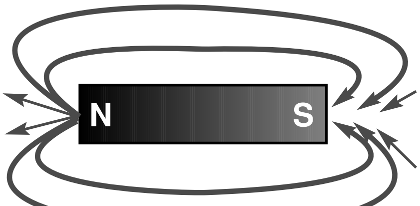
For example, if the golf club swings and misses the ball, no force would act on the ball and it would not move.

There are also some forces which can act on things without touching them...

Gravity
Electrical Force
Magnetic Force

How can gravity, electrical and magnetic forces reach out through space and apply a force to things without touching them?

To understand this, we use the "model" of a "force field".



For example, we imagine that a magnet is surrounded by an invisible web of forces. If certain things come within this "field", a magnetic force will push or pull on them.

The rest of this topic is all about "Field Forces".

Please complete Worksheet 4 before going on.

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The Force of Gravity

What Goes Up, Must Come Down

If you throw a ball vertically upwards it goes up, and then falls vertically down again. If you throw it upwards at an angle it follows an arc and curves back down to the ground.

The ball, and every other object on or near the Earth is being pulled toward the Earth by the force of gravity.

Gravity reaches out and pulls on things without touching them. It's as if the Earth is surrounded by an invisible "field" of force which attracts all objects.

How Does Gravity Work?

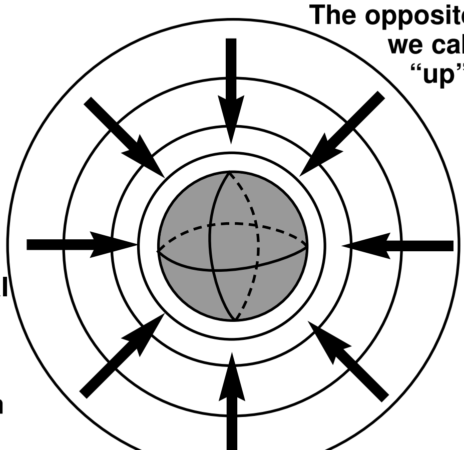
We still don't fully understand what causes gravity, but we do know that:

Gravitational Force attracts every object in the Universe to every other object in the Universe.

Gravity holds the planets in orbit around the Sun, and holds entire galaxies together. More on this in another topic!

The direction things fall is what we call "down". The opposite we call "up".

Everything is pulled by gravity towards the Earth, in the direction of the arrows.



Gravitational force gets weaker as you get further from the Earth

In this diagram, the circles represent the "Force Field" of gravity.

Mass and Weight

Gravity pulls on all objects because of their "mass". Mass is a measure of how much matter, or how much "substance", an object contains.

Mass is measured in kilograms (kg).

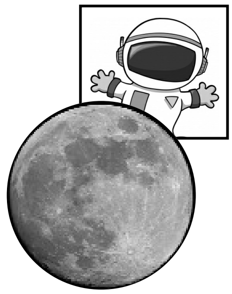
Unfortunately, in everyday life there is confusion about "mass" and "weight". When a person says "I weigh 65 kg" they really should say "My mass is 65 kg... my weight is about 650 N".

Weight is the force of gravity acting on your mass. Since weight is a force it is measured in newtons (N), NOT in kg!

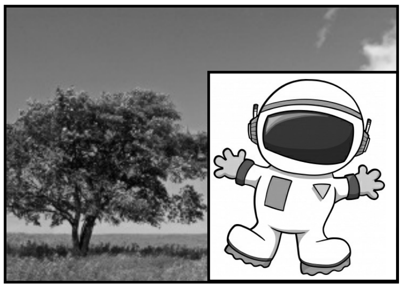
The strength of this force depends on where you are within a gravitational field, so the same object can have different weights in different places. Its mass remains the same, but the weight can change!

You might do an experiment in class to learn about the relationship between mass and weight here on the surface of the Earth.

Astronaut on the Moon
Mass = 100 kg
Weight = 160 N
(Moon's gravity is much less than Earth's)



Astronaut in Orbit in Space Station
Mass = 100 kg
Weight = zero N



Astronaut on Earth's Surface
Mass = 100 kg
Weight = 1,000 N

Mass is always the same. Weight changes.

Please complete Worksheet 5 before going on.

Orbits & Being Weightless

Most people know that when the astronauts are up in orbit in the Space Station (or other spacecraft) they are weightless. Many think that this is because there is no gravity up there in space. WRONG!

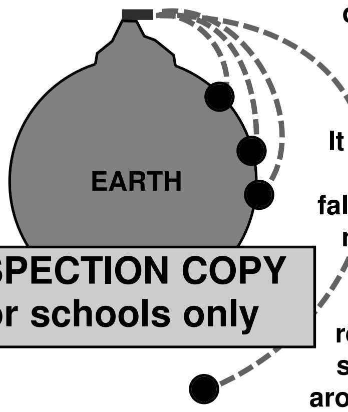
Without gravity, they would not even be able to stay in orbit and would fly off into deep space.

Gravity & Orbiting

It was Sir Isaac Newton (again!) who first figured out how orbiting is possible. He imagined a cannon on a very high mountain, firing cannon balls horizontally.
Study the diagram on the right.

This is how satellites are put in orbit, but using rockets, not cannons. They are not fired straight up, but up at an angle to eventually get them flying parallel to the ground at orbital speed.Then, turn off the engines and let them fall... gravity holds them in orbit.

When fired, a cannon ball curves downwards until it hits the surface. If fired faster, it goes further before hitting the ground.



If fired fast enough, the cannon ball curves downwards at the same rate as the Earth curves.

It will now circle the whole Earth! It is falling down, but cannot hit the surface.

If there is no air resistance (no air in space!) it can orbit around and around the Earth, always falling due to gravity.

Orbital Speed needed to orbit the Earth varies with height, but is about 25,000 km/hr

All Objects Fall at the Same Rate

Try This:
Drop a heavy object (e.g. a brick) and a light-weight object (e.g. a sheet of paper) from the same height at the same time. Watch carefully to see which hits the ground first.

The brick wins! Heavy things fall faster!
Wrong!

The paper was slowed down by air resistance, so your test wasn't fair. Scrunch the paper into a ball (this reduces air resistance) and try the test again. Without air resistance, all objects fall at the same rate due to gravity.

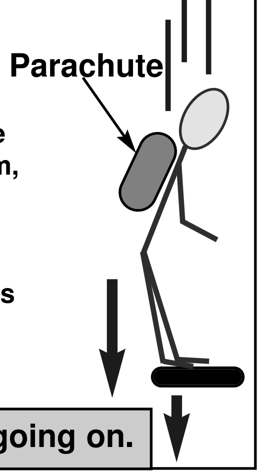
Weightless in Free Fall

Your weight is the force pulling you downwards due to gravity. To measure your weight you allow your weight-force to push against the springs in (say) a set of scales.

What if you stood on these scales in an aircraft, then jumped out feet-first with the scales glued to the soles of your feet? Falling feet-first with the scales still in position, you read your weight. ***The scales read zero! Why?***
(they would read zero if there was no air resistance)
Simple! You and the scales are both falling at the same rate due to gravity.

Since you and the scales are falling at the same rate, you are not pressing on them at all, so they read zero.

The same thing happens to the astronauts in orbit. They are in a free-fall orbit and while falling they are weightless. They still have their mass, and gravity is still pulling on them, but there is no weight force.



You can get small changes in your weight by standing on scales in a lift. As the lift first begins to move down, your weight becomes slightly less. As the lift first moves upwards your weight becomes a little more.

If you can't arrange to have scales with you in a lift, just feel the weight changes... they really happen.

Please complete Worksheets 6 & 7 before going on.

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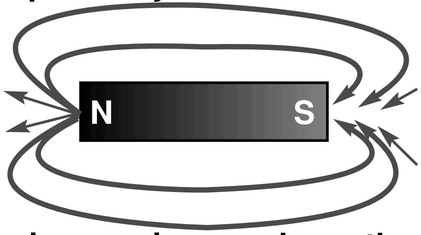
Magnetic Forces

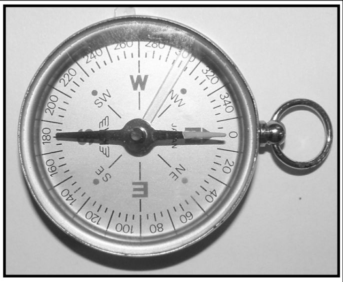
Magnets are surrounded by an invisible force field which acts on some substances. If certain types of materials come within the field they will be attracted, and pulled by a force.



Magnets can also repel, or push another magnet away.

Magnetism can be created from electricity, and we know that all magnetism is actually due to electricity within substances.

The Earth also has some magnetism.



The Earth's magnetic field is why a compass can tell us directions.

The magnetic field of the Earth is also important in protecting us from dangerous radiations from the Sun, and produces the beautiful and eerie "aurora" which can be seen in the sky from places near the North or South Poles.

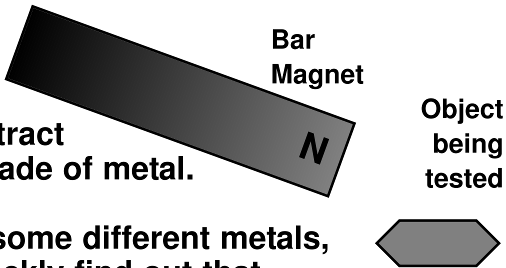
Experiments With Magnets

There are many ways to investigate magnetism. You may do some as class experiments and/or your teacher may demonstrate.

What Can Magnets Attract?

You might carry out a simple investigation with a bar magnet to find out what substances are attracted to magnets.

Some people think that magnets attract anything made of metal.



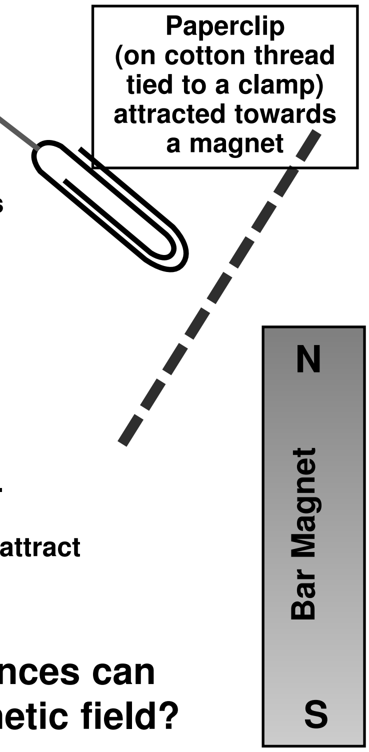
If you test some different metals, you will quickly find out that magnets only attract "ferrous metals". ("Ferrous" = iron)

These are metals containing iron, and include many types of "steel" (e.g. stainless steel). "Steel" is a metal made of iron mixed with some carbon and may include a variety of other metals mixed in.

It's the iron that a magnet attracts.

Investigating the Magnetic Field

Here's another simple investigation you might do.



To investigate the magnetic field, try holding a variety of thin sheets of different materials where the dotted line is in this diagram.

Try paper, plastic, glass and a variety of different metal sheets, if available.

Try a bunsen gauze... it's metal, but not solid.

Can the magnetic field attract the paperclip through solid substances?

Which substances can block the magnetic field?

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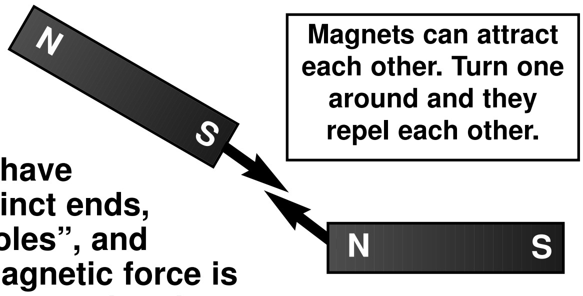
How Magnets Affect Each Other

If you place a bar magnet on the bench and slowly bring another bar magnet towards it you'll quickly find out several things:

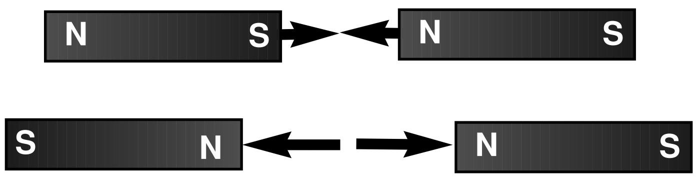


They have 2 distinct ends, or "poles", and the magnetic force is concentrated at the poles.

This is often summarised as follows:

Opposite poles attract.
Like poles repel.

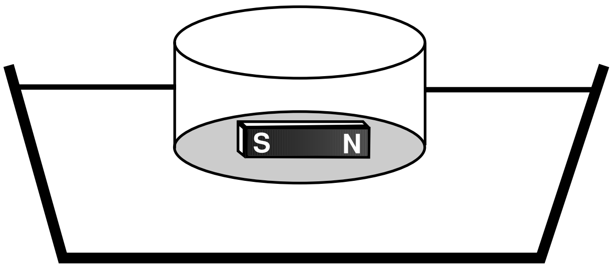
Opposite poles attract



Same poles repel

Finding Directions with a Compass

Place a bar magnet in a small plastic container and float it in a tub of water. You'll see that the magnet and floating container will swing arround to always point in a particular direction.



The end of the magnet marked "N" always points in the direction of north.

The "N" end of the magnet is called the "north-seeking pole" of the magnet, because it seeks out and points to the Earth's magnetic north pole.

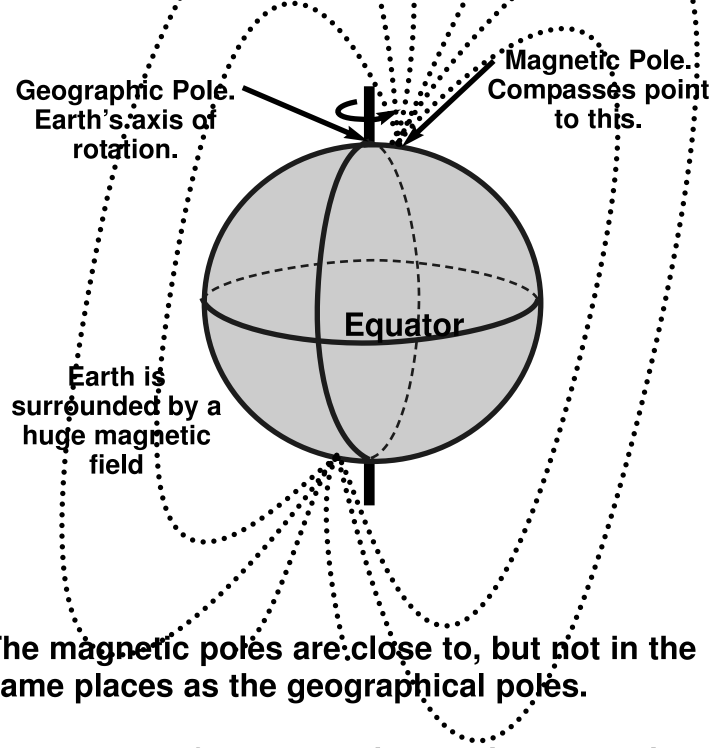
Since the "N" end is attracted towards the Earth's north pole, it follows that the "N" end is actually a magnetic south pole.

Confusing?
That's why it should be referred to as the "north-seeking pole".

Earth's Magnetic Field

The Earth's geographical poles are the points around which the Earth rotates on its axis.

The Earth also acts as if there was a huge bar magnet inside it and has a magnetic field with north and south magnetic poles.



The magnetic poles are close to, but not in the same places as the geographical poles.

A compass, of course, points at the magnetic poles. This is close to true north and south, but not quite the same.

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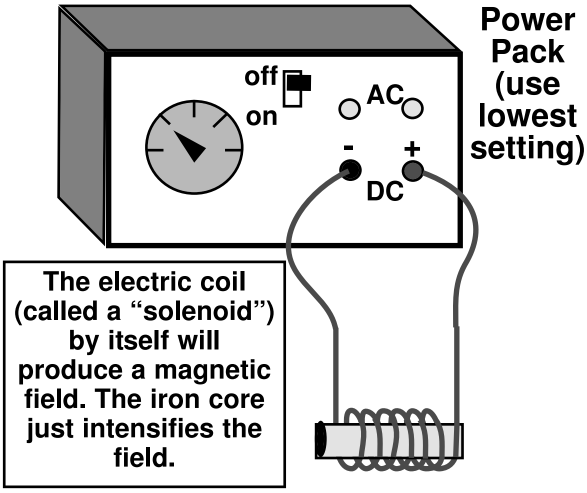
Electromagnets

Magnetism can be made from electricity.

Wrap insulated wire around a bar of soft iron. (A large bolt will do.) Connect to a power pack and turn on an electric current.

The iron bar becomes instantly magnetic, which you can prove by using it to attract paper clips or similar.

Turn it off, and most of the magnetism instantly stops. (Some may linger for a while.)



Uses of Electromagnets

The electromagnet is one the most useful devices ever invented.
Electromagnets are the basis of the electric generators which we use to make all our electricity in power stations.

Electromagnets are also the main part of all electric motors which we use in power tools, machinery, and many household appliances.

Electromagnets are also the main part of speakers in radios, TVs, public address systems, etc.

The electromagnets in a speaker are able to convert electricity into sound by making the speaker vibrate. This makes sound waves in the air.

Technology Makes Life Easier

Electromagnets are the basis of some of the of most important technologies our society depends on... electrical motors & generators.

These technologies make our life and work easier and more convenient.

In the Home	Factories & Workshops
washing machine	power tools
vacuum cleaner	machinery
refrigerator	conveyors
fans & hair driers	pumps & compressors

Each of these devices works because of an electric motor, which runs on electricity produced by a generator (at a power station).

Think about how each device makes life or work easier and more convenient.

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The Magnetic Field

We can easily see the effects of a magnetic field, but we can never actually see the field... or can we?

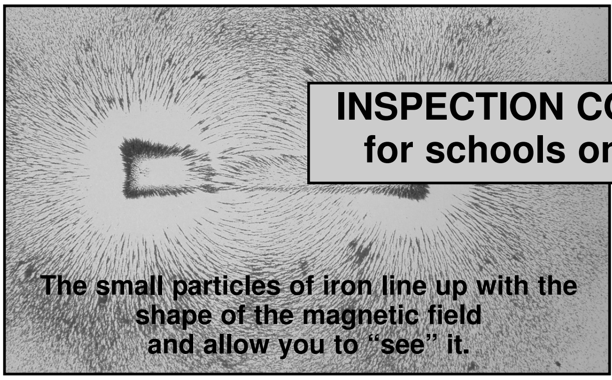
Firstly, place a bar magnet inside a plastic bag or wrap it in cling film.

Then place a sheet of stiff paper over it. Sprinkle the paper with powdered iron granules. Now gently tap the paper and watch the pattern develop.

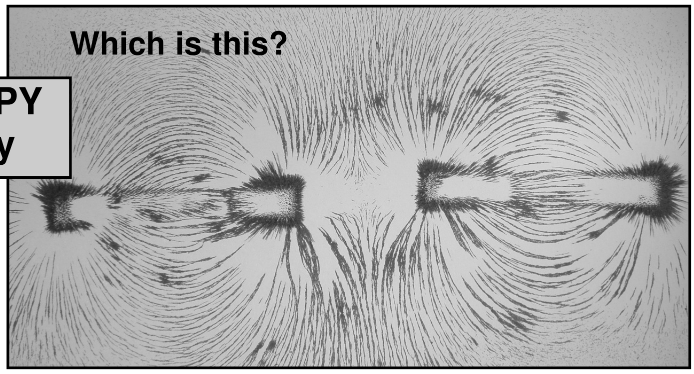
Instead of using paper, your teacher might demonstrate this using a clear plastic sheet on an overhead projector.

As well as a single magnet, try using 2 magnets which are attracting each other,

or 2 magnets repelling each other.



The small particles of iron line up with the shape of the magnetic field and allow you to "see" it.



Mapping a Magnetic Field with a Compass

Another way to understand and to "see" a magnetic field is to map it using a compass to find the direction of the "magnetic field lines" at various points.

Place a solenoid coil on a blank piece of paper and connect to a power pack on very low voltage. Now place a compass on the paper and see which direction it points.

Draw an arrow on the paper to show which way the north-seeking end of the compass points.

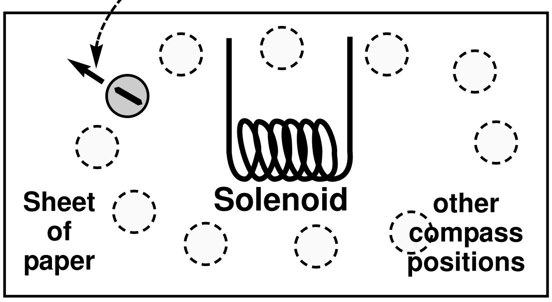
Now move the compass to a variety of other places on the paper and repeat the "mapping". You might even be able to place the compass inside the coil.

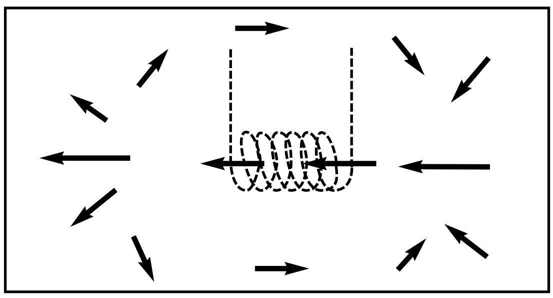
You may end up with a pattern similar to this sketch.

Can you see from this pattern that the magnetic field produced by an electrical coil (and an electromagnet) is more or less the same shape as the field of a bar magnet?

Can you tell which end of the coil was the N-seeking pole?

Draw an arrow to show which way the N-seeking end of the compass points





Please complete Worksheets 8 & 9 before going on.

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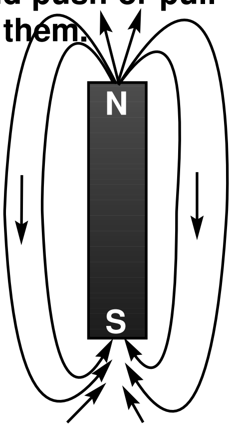
How Scientific "Models" and Theories Help Us to Understand Things

Sometimes it's very difficult to understand strange natural things like gravity, or magnetism.

To help us understand such things we use scientific "<u>models</u>".

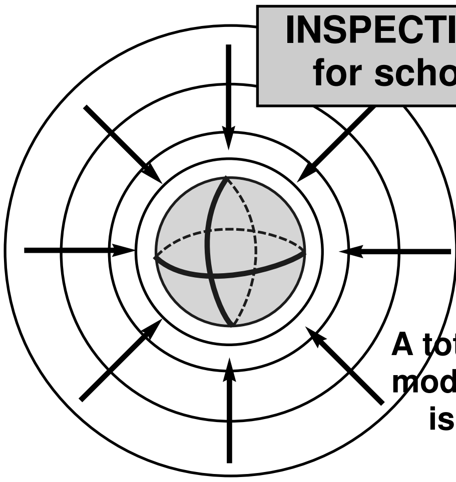
For example, the idea of a "<u>Force Field</u>" is a model to explain how some forces can reach out through space and push or pull on things without touching them.

Our explanation of magnetism is that a magnet is surrounded by an invisible field of magnetic forces, and we use diagrams like this to help visualise the field.



We explain gravity by imagining that the Earth is surrounded by an invisible force field which attracts mass.

Are these models true and real? Are there really invisible force lines everywhere?

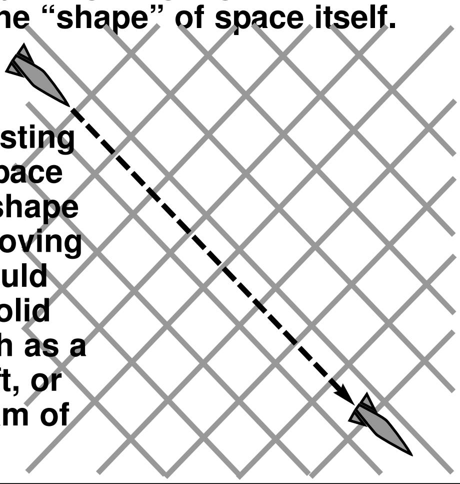


A totally different model for gravity is described below...

Scientific Models *cont.*

The force-field model is not the only way to explain gravity.

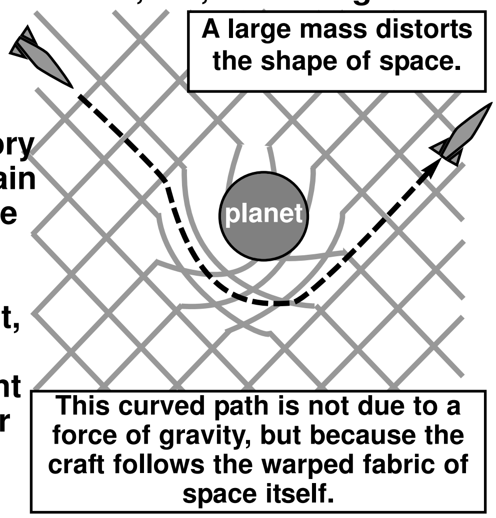
Einstein's "<u>Theory of Relativity</u>" explains gravity in a totally different way. According to this theory, empty space itself has a certain geometry or "shape". We can model this by imagining a grid which represents the "shape" of space itself.



Things coasting through space follow the shape of space. Moving things could include solid objects such as a space craft, or even a beam of light.

Einstein's theory is that mass causes the shape of space to be warped or distorted. Moving things still follow the geometric grid, so near a massive object such as a planet, the space craft follows a curve which may lead it down to the planet's surface, or into orbit, etc, according to its speed.

Einstein's theory is able to explain things that the "force-field model" of gravity cannot, such as the bending of light travelling near stars.



Even if a model is not the full reality, it is still useful if it helps us understand the facts we observe in the Universe. The "force-field model" of gravity is ideal to explain the facts of gravity in everyday events here on Earth. In the wider Universe of massive stars and black holes, Einstein's "warped space model" is necessary to explain what we see.

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Electrical Force

In an electric circuit there is a flow, or current, of electrical charges moving through a conductor.

Materials which are electrical insulators (e.g. plastic) will not allow a current to flow, but they can develop an electrostatic charge. ("static" = not moving)

Electrostatic charges can exert a force (push or pull) on each other and cause many strange effects.

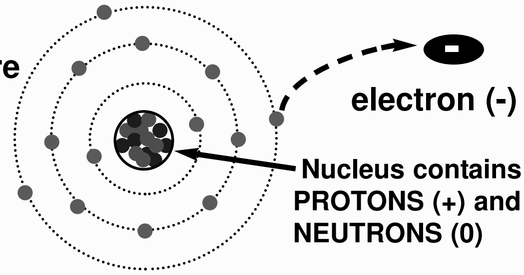
**Electrons carry negative electric charge.
Protons carry positive electric charge.**

Electrical Charge

You need to be aware that every substance is made up of tiny units of matter called atoms.

Each atom often acts as if it was a tiny solid ball, but in fact it is composed of smaller particles arranged as in this diagram.

Structure of an ATOM



The little electrons are whizzing around the central nucleus, like miniature planets around the Sun.
(Note: this is NOT a gravitational orbit,)

Each electron, and each proton in the nucleus, carries a field-force which we call electrical charge.

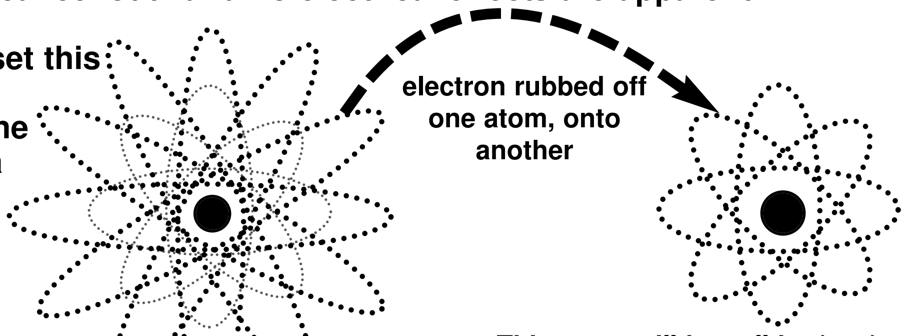
There are 2 opposite types of electrical charge which have been called simply "positive" (+ve) and "negative" (-ve).

How Things Get an Electrical Charge

Normally, the number of electrons & protons in each atom is exactly the same. The +ve charges and the -ve charges "cancel out" and no electrical effects are apparent.

However, it is very easy to upset this balance by transferring electrons from the atoms of one substance onto the atoms of a different substance.

Gentle friction is enough. Just rubbing different substances together can transfer electrons from one to the other.



This atom still has all its (+ve) protons, but has lost a (-ve) electron. Overall, it now has a (+ve) charge.

This atom still has all its (+ve) protons, but has gained a (-ve) electron. Overall, it now has a (-ve) charge.

If these substances are electrical insulators, the charges cannot flow away, so the substance stays charged, at least for a while.The charges can push or pull each other (FORCE!) because each has a force-field.

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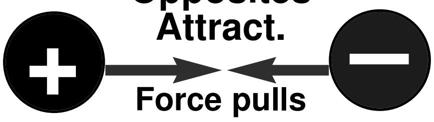
Forces Between Electrical Charges

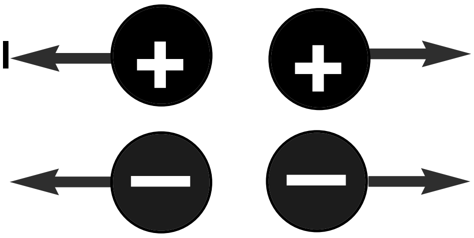
How do electrical charges affect each other?
It turns out to be very similar to the pattern of forces between magnetic poles.

Opposites Attract.



Force pulls them together

Same Charges Repel each other. Force pushes them apart.

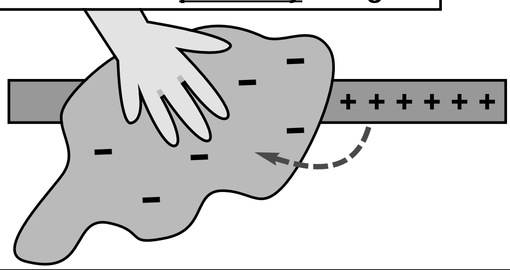


Getting Charged

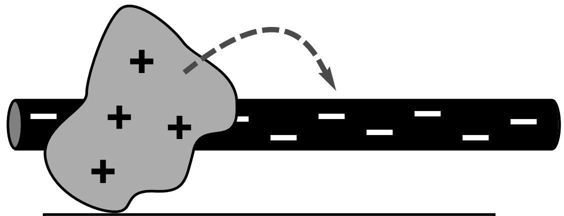
To investigate electrical charge you will probably experiment by rubbing different materials together.

One of the best combinations is to rub perspex (a clear plastic) with silk.

Electrons rubbed off perspex rod.
Rod becomes positively charged.



If you rub an ebonite rod (ebonite is a hardened rubber substance) with wool, it becomes negatively charged.



Electrons rubbed off wool cloth.
Rod becomes negatively charged.

Only the (-ve) electrons move.
The (+ve) charges (protons) cannot move because they are fixed in the nucleus of the atoms.

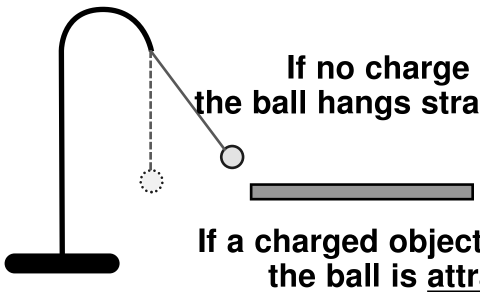
Electroscopes

An electroscope is a device which detects electrical charge, and allows you to study it.

There are various types of electroscope you might use, or see demonstrated.
The simplest type is shown here.

Ball Electroscope

This is simply a light-weight ball (e.g.poly-styrene) hanging on a fine silk thread.

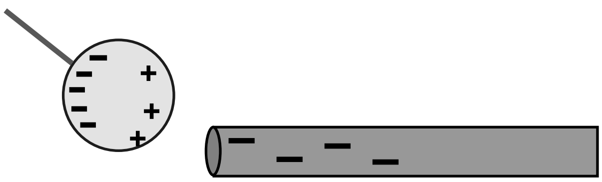


If no charge is present, the ball hangs straight down.

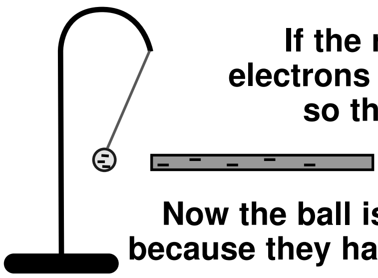
If a charged object is nearby, the ball is attracted to it.

Why is the Ball Attracted?

When a charged rod comes near, some electrons in the ball move, causing a separation of charges.



The rod then attracts the nearer charges, and the ball is pulled towards the rod.



If the rod touches the ball, electrons transfer (rod to ball) so the ball gets the same charge as the rod.

Now the ball is repelled by the rod because they have the same charge.

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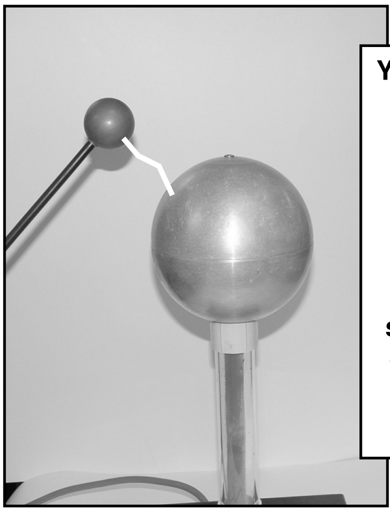
Static Discharge

Things can get charged up, and they can also lose their charge again. Often, they lose their charge by a "SPARK" jumping. A spark occurs when millions of electrons jump through the air.

A spark discharge always involves electrons jumping from a negatively charged object towards a more positively charged object. Remember, only the (-ve) electrons can move.



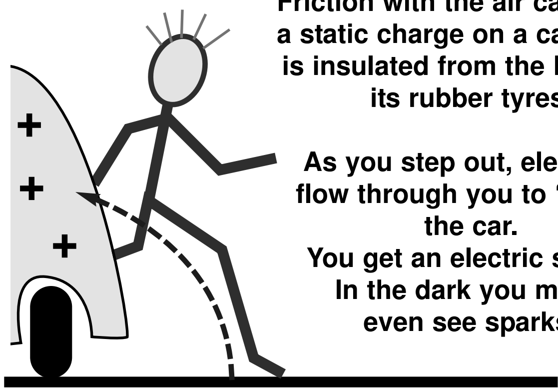
You may have seen a "van der Graaf" generator in action in the laboratory. It develops strong electrical charges which are great for studying the effects of charge, and also great for making discharge sparks!

Earthing a Charge

The Earth itself is such a huge lump of atoms that it can easily supply electrons to, or accept electrons from, a charged object.

So, if electrons can flow between a charged object and the Earth, either by sparking or by flowing through a conductor, they will. The charged object loses its charge. we say it has been "earthed", or "discharged".

Ever been "zapped" as you step from a car?



Friction with the air can create a static charge on a car, which is insulated from the Earth by its rubber tyres.

As you step out, electrons flow through you to "earth" the car. You get an electric shock. In the dark you might even see sparks!

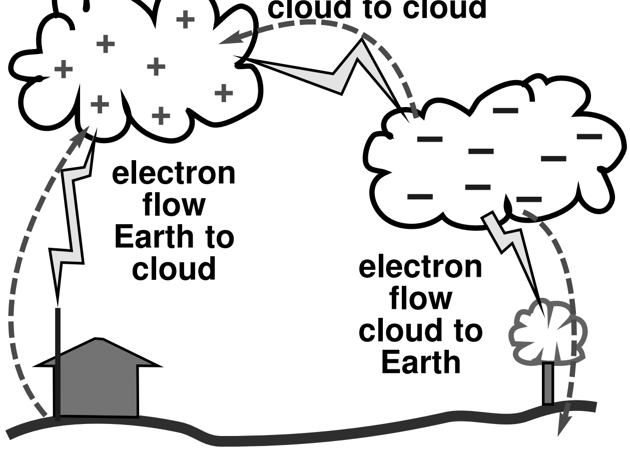
Lightning

The ultimate in an "earth discharge" is lightning.

Violent winds inside a "thunderstorm" system cause static charges to build up in the clouds.

Some clouds become (+ve) and others (-ve).

Eventually, they may discharge by sparking, either from one cloud to another, or by "earthing".



A "lightning rod" protects buildings by providing a conducting pathway for electrons to flow through.

As the electrons force their way through the air, a narrow channel of air is heated to very high temperature and glows briefly. That is the flash of lightning.

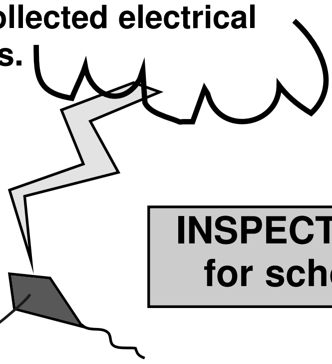
The sudden expansion of air in this "super-heated" channel of air creates a shock wave of sound. This shock wave is the sound of "thunder".

Please complete Worksheets 10 &11.

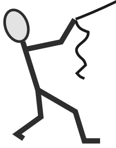
How Scientific Knowledge Has Changed Our Understanding of the World

Many ancient people thought that thunder and lightning were caused by angry gods in the sky.

In 1752, the American Benjamin Franklin carried out a famous (and incredibly dangerous) experiment. He flew a kite into a thunderstorm and collected electrical charge from the clouds.

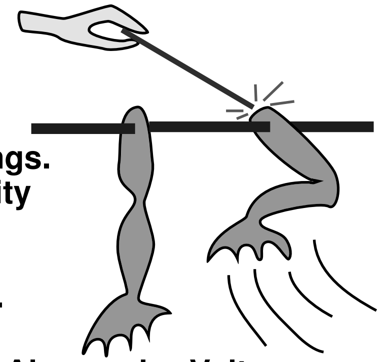


From this he was able to show that lightning was electrical and could be studied scientifically. It no longer needed a supernatural explanation.



About 30 years later, 2 Italian scientists studied electricity in a different way.

Luigi Galvani discovered that freshly dissected frog's legs would twitch and jump if touched with metal wires.



He believed that there was "animal electricity" in them, and in all living things. He thought electricity was a "life force", possibly of supernatural origin.

But another Italian, Alessandro Volta believed the electricity making the frog's legs jump was not some supernatural force, but simple chemistry. He began experiments to prove his ideas.

Over a 20 year period, the experiments and arguments went back-and-forth until eventually Volta was proven correct.

The explanation was that the muscles were still alive and functioning for a while after being cut from the frog. Electricity from a chemical reaction between the metal wires and the frog's body fluids made the muscles twitch.

Alessandro Volta went on to invent the first practical electrical battery to make usable amounts of electricity. This allowed many later scientists to study electricity and gradually gain a full understanding of both static and current electricity. Many inventions followed, leading to light bulbs, electric motors and appliances, etc.

In his honour, we have named the electrical unit, the "volt", after Alessandro Volta.

The work of Ben Franklin and Volta was the start of a series of developments which led directly to our modern electrically-powered world. However, their work led not only to the new electrical technologies, but helped change the way people understand the natural world.

People gradually began to see that mysterious things like lightning, the Universe, or even life itself, could be understood scientifically without the need for supernatural explanations.